MONITORING THE QUALITY OF AIR

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Summary

Over the last few decades, it has become evident that in order to better understand the chemical, physical and dynamical processes governing the behaviour of the atmosphere, global knowledge of the abundance and distribution of atmospheric constituents is required. An improved aspect of this knowledge is the ability to monitor air quality by using satellites and Geographic Information System (GIS).

Several mathematical models have been used to simulate atmospheric and chemical processes leading to environmental problems such as global warming and ozone depletion layer. However, because these atmospheric processes are often nonlinear, detailed and complex models are needed. Such models require significant amount of graphical and statistical analyses for interpretation and verification.

Therefore, software tools with spatial functionality, such as Geographic Information System (GIS) provides an efficient and flexible tool for creating information products.

Refined air quality models and a variety of emission management conceptual designs have been developed using GIS.

On the other hand, the only feasible method of obtaining global information regarding the distribution of different atmospheric chemicals is from instrumentation aboard satellites. Several space-born satellite based experiments have been designed to monitor air pollutants in the atmosphere.

These include the Global Ozone Monitoring Experiment (GOME), the Measurement of Air Pollution from Satellites (MAPS), the Stratospheric Aerosol and Gas Experiment (SAGE), Halogen Occultation Experiment (HALOE) and other programs that will be addressed in this study.

Satellite observations have an important advantage over the traditional measurement methods that is the possibility to observe both the temporal and spatial variations within the atmosphere allowing for global monitoring of air quality.

1. Introduction

There is a need to develop more efficient and more accurate tools for global monitoring of air quality. A variety of air pollutants have contributed to major environmental problems which are cause of concern on a global basis.

As examples, global warming or the greenhouse effect and ozone layer depletion are perturbations resulting from the presence of certain anthropogenic gaseous compounds in the atmosphere which have specific radiation absorption characteristics. Such chemicals need to be better studied and controlled.

According to the World Meteorological Organization (WMO), increase in concentrations of greenhouse gases such as carbon dioxide (CO_2), nitrous oxide (N_2O), methane (CH_4), dichlorodifluoromethane (CF_2Cl_2), trichlorofluoromethane ($CFCl_3$) and chlorofluorocarbons (CFCs) have contributed to global warming problem (Fig. 1).

These gases are known for their atmospheric absorption potential of the outgoing infrared wavelength radiation to various extents. The net result would be an increase in the average temperature of the earth's surface and lower atmosphere since the quantity of solar radiation during the day would be unchanged while the terrestrial radiation back to space would be reduced.

In the 1980s, the increase in concentration of these gases ranged from 0.5 % / y for CO_2 to 4 % / y for other anthropogenic compounds. During the last hundred years, the global mean surface air temperatures have also risen by approximately 0.4 to 0.8 ^{0}C. According to their calculated relative contributions to reducing the transparency of the atmosphere, it was demonstrated that CO_2 contributed more than half (55 %), followed by the CFCs (19 %), methane (15 %) and N_2O (6 %). It is to be noted that the strongest contributor to reducing transparency and absorbing infrared (IR) is water vapor (H_2O). However, humans do not directly influence its concentration in the atmosphere.

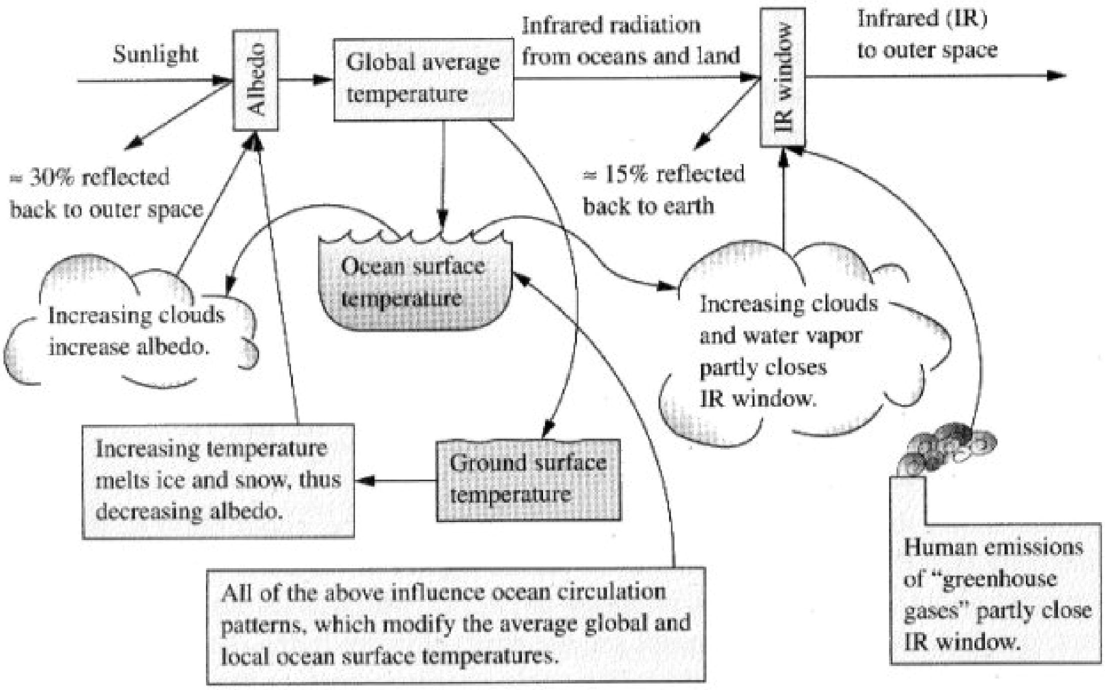

Figure 1 : Interactions involved in the global warming problem. (Source de Nevers, 2000)

On the other hand, increasing the global temperature by adding greenhouse gases will have positive and negative effects on the albedo by increasing cloudiness and melting of ice with substantial rise in the level of the oceans. Best current estimates suggest that the overall effect of such increased cloudiness would be the reduction of incoming solar radiation which would tend to slightly cool the earth. Hence, the form these changes will take is unknown. Large-scale computer modeling of the atmosphere suggests only what would happen, but the calculations are still considered relatively speculative. Moreover, the inadequacy of existing global transport models and uncertainties in the current understanding of the fate of greenhouse gases is a major concern.

The second global problem concerns the destruction of the stratospheric ozone layer. Ozone is another gas which absorbs the sun's radiation but in the range of short wavelength ultraviolet radiation (UV). Therefore, its presence in the lower atmosphere, or stratosphere, is beneficial in that it absorbs a significant amount of the sun's UV radiation known to have a potential for causing detrimental effects on the earth's ecosystem. Controversially, tropospheric ozone or urban ozone, formed as a result of photochemical reactions in the earth's surface boundary layer is a strong eye and respiratory irritant and a major component of photochemical smog. It is ironic to note that tropospheric ozone is a strong air pollutant, whereas, stratospheric ozone is a life protector.

During the last two decades, the stratospheric ozone mass has decreased significantly due to the presence of anthropogenic gases such as chloro- and hydrochloro-fluorocarbons (CFCs and HCFCs). These gases, emitted at ground level have eventually dispersed into the stratosphere causing ozone depletion. Destruction of the ozone (O_3)

layer is mostly caused by elemental chlorine atoms by a mechanism involving the following two reactions:

$Cl + O_3 \rightarrow ClO + O_2$

$ClO + O_3 \rightarrow Cl + 2\ O_2$

One chlorine atom can convert many ozone molecules to ordinary molecular oxygen. Estimates show that one Cl atom may destroy 10^4 to 10^6 O_3 molecules. The detected ozone depletion layer has been observed in both the northern and southern hemisphere, being more important in the stratosphere over Antarctica. Nevertheless, due to the phasing out of these chemicals, their concentrations have been substantially reduced. However, their lifetimes in the atmosphere are in the range of hundred years, and some of them are persistent .

By the clear concerns over greenhouse gases and ozone depletion, atmospheric absorption and related scavenging mechanisms for specific compounds play critical roles in keeping the world's ecosystem in balance. Scientists understand how delicate that balance actually is.
Consequently, it has become evident that global knowledge of the abundance and distribution of atmospheric constituents is required for better understanding the chemical, physical and dynamical processes governing the behaviour of the atmosphere. An improved aspect of this knowledge, is the ability to monitor air quality through the use of the Geographic Information System (GIS) and satellite measurements. Monitoring air quality using these techniques provide scientists with the only near-global database of atmospheric pollutant levels.

2. Air quality monitoring techniques

2.1 Geographic Information System (GIS)

The Environmental Protection Agency (EPA) uses several mathematical models to simulate atmospheric and chemical processes leading to air pollution problems. These models need to be complex because atmospheric processes are often non-linear, and significant amount of graphical and statistical analyses are required for verification and interpretation of predictions. Therefore, software tools with spatial functionality, such as Geographic Information Systems (GIS) are useful tools which may be used by both researchers and policy analysts.

2.1.1 GIS Overview

During the past several years, conventional cartography has been largely replaced by automated mapping using digitized representations of map features. One such example is the GIS that is defined as " a computer system that stores and links non-graphic attributes or geographically referenced data with graphic features to allow a wide range of information processing and display operations, as well as map production, analysis, and modeling". These computer based tools manage a variety of data identified by their geographic locations or spatial references.

In general, a GIS is composed of a database, a spatial or map information and means to link these two data. The linking of data to maps or drawings provides a powerful tool for increased visibility and insight into the extent of areal contamination in certain pollution cases. Studied information may include topological characteristics, meteorological parameters, properties of geometrical objects such as points, lines and areas together with the contamination level of one or more chemicals at a specific sampling site. GIS data include also county boundaries, land use and pollution-monitoring locations.

Such technique provides an efficient and flexible tool for creating information product for location studies, scientific investigations, natural resource management and planning development.

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Biographical Sketch

Dr. Samia Gamati has been working in the field of environmental biochemical bioengineering since she received her Ph.D. degree in 1988. Following her post-doctoral fellowship at the Biotechnology Research Institute, Montreal, National Research Council Canada, she joined the environmental biotechnology department at that Institute. She is adjunct associate professor at Concordia University, Montreal, teaching and supervising student research studies in the Building, Civil and Environmental Engineering department. She also works in the environmental engineering industry as R & D manager at Sodexen Group, Montreal.